Available online at www.sciencedirect.com
SciVerse ScienceDirect
Procedia Computer Science 19 (2013) 289 – 296
Procedia Computer Science

The 4th International Conference on Ambient Systems, Networks and Technologies (ANT 2013)

Forwarding Group Maintenance of ODMRP in MANETs

Fayez Khazalah[a], Ismail Ababneh[b], Zaki Malik[a]

[a]*Department of Computer Science, Wayne State University. Detroit, MI. USA.*
[b]*Department of Computer Science, Al-alBayt University, Mafraq, Jordan.*

Abstract

ODMRP builds and refreshes routes by flooding Join Queries periodically. However, excessive flooding wastes the limited bandwidth of ad-hoc networks and causes high control overhead. In addition, flooding often causes congestion and collisions. Finding the optimal flooding interval is critical in ODMRP performance. Moreover, there is no such value for flooding interval that is appropriate for all various types of ad-hoc network applications. The present paper aims to reduce the high control overhead that ODMRP suffers from. We propose two schemes to improve this protocol. Both schemes use the link state prediction method that depends on the received signal power strength for predicting the exact link breakage time of an active link before the breakage actually occurs. By using link state prediction, routes are reconstructed only when they will be soon broken, and thus we utilize the bandwidth efficiently and reduce the power consumption when the mobility of nodes is low. The proposed two schemes are ODMRP-GM and ODMRP-LM. In ODMRP-GM, source nodes flood Join Queries only when the topology is changed. In ODMRP-LM, routes are updated locally by the nodes that predict future breakage time of an active route between refresh intervals. The impact of our improvements is evaluated via simulation.

Selection and peer-review under responsibility of Elhadi M. Shakshuki

Keywords: MANETs, Multicast, Routing, ODMRP

1. Introduction

A Mobile Ad-hoc Network (MANET) is a temporary, auto-manageable, auto-configurable wireless network that does not need a fixed infrastructure or a central administration [1]. Some applications of MANETs include industrial and commercial applications, military communication, and emergency and safety operations [2]. Due to the limited radio propagation range, if two hosts are not within direct wireless transmission range of each other, the communication between them must pass through one or more other hosts [1] [3]. The nodes in MANETs usually move arbitrarily. Therefore, the network topology changes frequently and unpredictably. Moreover, bandwidth and battery power are limited [2]. ODMRP floods Join Queries periodically to create and update multicast Forwarding Groups and routes; As a result, this excessive flooding causes control overhead to soar. Because the performance of ODMRP depends highly on the value of the refresh interval, selecting the right value of the refresh interval for each application of MANETs is not an easy decision [4] [5]. In this paper we present an enhancement for ODMRP to decrease its high control overhead cost. This enhancement utilizes received signal power strengths to predict the exact breakage time

Selection and peer-review under responsibility of Elhadi M. Shakshuki
doi:10.1016/j.procs.2013.06.041

of active routes in advance. Thus, active multicast routes and Forwarding Groups can be refreshed on time to avoid data packets losses.

The rest of this paper is organized as follows. Section 2 is an overview. It describes the ODMRP protocol, an explicit join scheme to improve the performance of ODMRP, a GPS-based mobility prediction scheme to adapt the Refresh Interval of ODMRP, and a scheme that uses the radio signal power strength for mobility prediction. In section 3, a research approach is introduced, and two schemes are proposed to improve the performance of ODMRP and decrease its high control overhead. Section 4 describes the simulation environment and the methodology used in this research. In section 5, the simulation results are discussed in detail. Finally, section 6 concludes this paper and suggests future work.

2. Overview

2.1. ODMRP

ODMRP is a mesh-based multicast protocol which is used in MANETs [6]. It establishes a Forwarding Group of nodes for each multicast group by considering the shortest paths between group members [7]. It then uses the established Forwarding Group to forward data between group members as illustrated in Figure 1. Nodes in ODMRP can join or leave a group freely without any notification message [4]. In ODMRP [6], source nodes are responsible for establishing multicast forwarding groups. As a source node has more multicast data to send, it periodically floods a Join Query packet to the entire network. Any node that receives a non-duplicate Join Query stores the upstream node address and rebroadcasts the packet. If a multicast destination node receives the Join Query, it first creates a Join Reply and then rebroadcasts it. Any node receives a Join Reply checks if it is on the path to the source. If so it will join the forwarding group of the targeted source of the Join Reply by setting the appropriate membership flag and then broadcasting its own Join Reply. The Join Reply is thus broadcasted by nodes that decide to join the forwarding group until it finally reaches the targeted source.

2.2. Explicit Join in ODMRP

An Explicit Join scheme is proposed in [2] to improve the performance of ODMRP. The Explicit Join reduces the number of dropped data packets due to link breakage in active routes through Join Queries. In this scheme, the receiving nodes are responsible for maintaining the active routes from the source to them so they can continue receive multicast data. To accomplish this task by receivers, each one must compute and maintain the data interval rate and update it continuously. If a receiver finds out that one or more data interval has passed without receiving any data, it is responsible for finding an alternative path to resume receiving multicast data again. In our study, we will use the concept of Explicit Join in the proposed Local Maintenance scheme to enhance ODMRP by reducing its high control overhead.

2.3. Adapting the Refresh Interval via Mobility Prediction

ODMRP requires periodic flooding of Join Queries to refresh routes and forwarding group memberships; as a result, control overhead is high, and bandwidth is utilized inefficiently. Furthermore, flooding often leads to congestion and collisions. The optimal refresh interval value, thus, has an influence on the performance of ODMRP [4] [8]. A scheme is proposed in [9] to adapt the refresh interval to mobility patterns and speeds. It uses the Global Positioning System (GPS) to predict the breakage time of an active route by utilizing the location and mobility information provided by the GPS. With the predicted time of route disconnection, Join Queries are sent only when the currently used routes are going to break imminently. The GPS, however, is currently not a standard component of mobile devices, and the signal strength is weak or even vanished in densely populated or indoor areas [10].

2.4. Mobility Prediction by Radio Signal Power Strength

To overcome the disadvantages of the GPS, another study proposed a link prediction algorithm to increase Packet Delivery Ratio in Dynamic Source Routing (DSR) protocol [10]. The algorithm can predict the link breakage time between two mobile nodes on an active route by measuring the received signal strength.

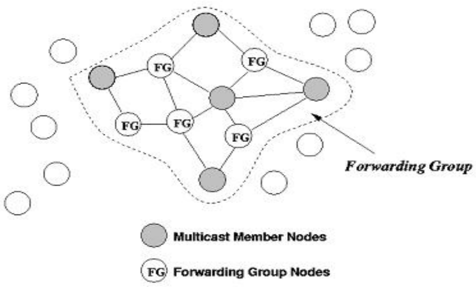

Fig. 1. Forwarding Group idea in ODMRP [11].

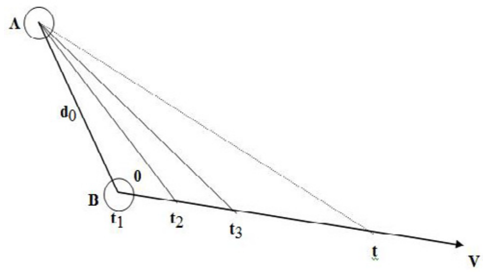

Fig. 2. Relative Movement of Two Mobile Nodes [10].

It uses the computation of the relative movement between two mobile nodes and the Two-Ray Ground Reflection Radio Propagation Model. From the view of node A, the movement of node B can be viewed in Figure 2. The following assumptions must be satisfied for the algorithm to predict the link breakage: the sender power level is constant and the two neighbor nodes keep their moving speeds and directions during the prediction time. When node A receives three consecutive radio signal powers from node B, it then can predict the link $A - B$'s breakage time as in the following equation:

$$t = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

Where

$$a = t_2 \sqrt{P_2 P_s} \beta$$

$$b = \sqrt{P_s}((\sqrt{P_1} - \sqrt{P_2}) - t_2^2 \sqrt{P_2} \beta)$$

$$c = t_2 \sqrt{P_2 P_s} - t_2 \sqrt{P_1 P_2}$$

$$\beta = \frac{(\sqrt{P_1 P_2} t_2 + \sqrt{P_2 P_3} t_3 - \sqrt{P_1 P_3} t_3 - \sqrt{P_2 P_3} t_2)}{(t_2 t_3^2 - t_3 t_2^2)\sqrt{P_2 P_3}}$$

P_s is the received signal power threshold and it is fixed for the wireless network interface. P_1, P_2, and P_3 are three consecutive signal powers received by node A from node B at times t_1, t_2, and t_3, respectively.

3. Research Approach

Our goal of this research is to implement the link state prediction method illustrated in equation (1) in ODMRP to adapt the broadcast of control packets to mobility patterns; as a result, the useless transmission of control packets across the network can be eliminated in case of low mobility patterns. We introduce two schemes to enhance ODMRP protocol: Global Maintenance and Local Maintenance. Both schemes depend on the previous equation, but each one applies a different implementation for routes and Forwarding Groups maintenance.

3.1. Implementation of the Prediction Algorithm

To implement the link prediction algorithm in ODMRP, we considered the following points:

1. Node A needs three consecutive packets received from its neighbor node B to be able to predict the time when the link $A - B$ will be broken.
2. The prediction algorithm is implemented only on multicast receivers and forwarding group nodes.
3. Each node monitors only data packets received from source or forwarding group nodes.
4. ODMRP needs a period of time (the Critical Period) to find an alternative route instead of the one that is predicted to be soon broken. This Critical Period should be big enough for node A to find a new route before the old one is broken. If the breakage time of the link $A - B$ is less than or equal to the current time + Critical Period, we say that the link enters the Critical State. As a result, Node A will immediately inform the source node about the imminent breakage of the current active route in the case of the Global Maintenance scheme, or it tries to find an alternative route as in the case of the Local Maintenance scheme.

3.2. A Global Scheme for Forwarding Group Maintenance in ODMRP

The Global Scheme (ODMRP-GM) uses the prediction algorithm to adapt the refresh interval to speed and mobility patterns. Join Queries are flooded by the source node only when the current active route is broken imminently. Thus, we can avoid the broadcast of unnecessary control packets across the network in case of low mobility patterns or if the topology doesn't change frequently. When node A executes the prediction algorithm and the prediction time is less than or equal to the current time + Critical Period, it creates a Predicted Route Error packet and sends it to the source node via the upstream node B. the Predicted Route Error packet contains the multicast group address and the source address.

Handling Predicted Route Error Packets Every node maintains a table called Link Table. Each entry of the Link Table has the source node address, neighbor node address, and the packet reception time. When node A receives a data packet from its neighbor node B, it will monitor its link status with node B using the prediction algorithm. If the link is in the Critical State, node A will check if the source node and neighbor node pair is in its Link Table. If an entry is found, node A realizes that it has already informed the source about the imminent breakage of link $A - B$. If no entry is found, node A will insert the source node and neighbor node pair with the current time into the Link Table.

When any intermediate node receives a non redundant Predicted Route Error packet, it searches for a route to the source node in its Route Table. If it finds an entry, it forwards the Predicted Route Error packet towards the source node. When the source node receives the Predicted Route Error packet, it creates a Join Query packet and floods it through the network to update the multicast routes and maintain the Forwarding Group.

When the node mobility rate is high and the topology changes frequently, routes will expire quickly and often. Consequently, the source may propagate Join Queries excessively and this excessive flooding can overflow the network with control packets and causes collisions and congestions. To avoid this problem, ODMRP-GM should impose a minimum value for the refresh interval by defining a Min-Refresh-Interval parameter. By imposing the minimum refresh interval, the source node will subtract the time when the last Join Query is sent from the current time. If the result is less than Min-Refresh-Interval value, then it will discard the Predicted Route Error packet and do nothing. Otherwise, the source node will flood a new Join Query.

Handling Join Queries When a source node receives the Predicted Route Error packet, it will create a Join Query packet and broadcast it across the network. A problem arises here when there are still some Join Query packets sent over the link $A - B$ that is still alive. As a result, some Join Reply packets may have routes that contain the link $A - B$. When a source node receives this kind of Join Replies, it may use this link that may break imminently again, and thus data packets will still be dropped.

We use the Link Table in every node to solve this problem. When node A receives a Join Query, it first checks if the previous hop node is in the Link Table. If it is recorded, it doesn't respond to the Join Query if it is a multicast receiver, else it stops rebroadcasting this Join Query further to its neighbors. The new routes, thus, will not contain the link $A - B$ anymore. The two nodes A and B may become neighboring nodes by moving closer sometime later because of the random movements of mobile nodes. Entries in the Link Table are removed when expired after a time-out period.

3.3. A Local Scheme for Forwarding Group Maintenance in ODMRP

The Local Scheme (ODMRP-LM) depends on increasing the refresh interval in ODMRP. When the mobility of nodes is low, then increasing the refresh interval will decrease the broadcast of control packets periodically over the entire network uselessly. As a result, the Control Overhead is reduced significantly. ODMRP-LM uses the prediction algorithm to predict the imminently link breakages. The nodes that predict that imminent breakage must try locally to find an alternative route keeps it connected to the source node to continue receiving multicast data. Thus, routes and Forwarding Group are maintained between Join Queries intervals in case of topology changes due to node mobility.

4. Simulation Model and Methodology

The Global Mobile Simulator (GloMoSim) [12] is used in our simulation. The GloMoSim is a scalable simulation environment for wireless network systems that uses the parallel discrete-event simulation capability provided by PARSEC [13]. Our simulation modeled a network of 50 mobile nodes placed randomly within a $1000m$ X $1000m$ area. The radio propagation range for each node was 250 meters. The bandwidth of the wireless medium was assumed to be 2 Mbps. The MAC protocol for the simulation is IEEE 802.11. We used the Random-Waypoint Model for node mobility. Constant Bit Rate (CBR) is used as a traffic source. The size of the data packet was set to 256 and the transmission rate to 10 packets per second. Each simulation scenario is executed for 600 seconds. Multiple runs with different seed numbers is performed for each scenario and collected data is averaged over those runs. We simulate one multicast group of size twenty with a single multicast source. The member nodes join the multicast group at the start of the simulation and remain as members throughout the simulation. The parameter values used for each protocol in our simulation are shown in Table 1. The following metrics are used to evaluate the performance of the simulated protocols [14]:

Table 1. Parameter values for simulated protocols.

Parameter	ODMRP	ODMRP-LM	ODMRP-GM
JOIN QUERY refresh interval	500 ms	3 s	X
Maximum JOIN REPLY retransmissions	3	3	3
Minimum-Refresh-Interval	X	X	500 ms
Maximum-Refresh Interval	X	X	3 s
Link Table timeout	X	X	2 s
Critical interval	X	100 ms	100 ms
Maximum-Hop-Count	X	3	X

- *Packet delivery ratio*: This metric represents the ratio of the total data packets successfully received by multicast members over the total data packets supposed to be received. It shows the effectiveness of a protocol in delivering data to the multicast receivers.
- *Control overhead*: The total number of control packets transmitted over the total number of data packets delivered. This metric shows the efficiency of control packets in delivering data packets to the targeted nodes.
- *Number of data packets transmitted per data packet delivered*: Data packets transmitted is the count of every individual transmission of data by each node over the entire network. This count includes transmission of packets that are eventually dropped and retransmitted by intermediate nodes.
- *Number of control and data packets transmitted per data packet delivered*: This metric shows the efficiency of channel access.
- *End-to-end delay*: This metric represents the time elapsed between the instant when the source has data packet to send and the instant when the destination receives the data.

5. Simulation Results

In this section, we will evaluate the performance of the proposed schemes in comparison with the original ODMRP protocol. We study the impact of node speed, multicast group size, data rate, and number of nodes on the evaluated protocols using the metrics mentioned before. We vary the speed of nodes between 0 and $30m/s$ for speed experimental set, and we keep a constant speed ($5m/s$) for the others. We vary the number of nodes in a multicast group between 10 and 40 for multicast group size experiment, 40% of the total number of nodes for number of nodes experiment, and we keep constant group size (20) for the others. lastly, we vary the data rate between 2 and 25 packets per second for data rate experiment, and we keep a constant data rate (10 packets per second) for the others. Due to the limited space, we analyze in details the performance of protocols when varying the mobility speed. For other experiments, we only include the results of control overhead as shown in Figures 7, 8, and 9. However, the results of all other experimental sets are very similar to mobility speed experiment, and show that the proposed schemes always have low control overhead while maintain the same packet delivery ratio as ODMRP.

Delivery ratio Figure 3 illustrates the packet delivery ratio of the simulated protocols under different speeds. We can see that both of ODMRP-GM and ODMRP-LM give slightly better performance than the original ODMRP.

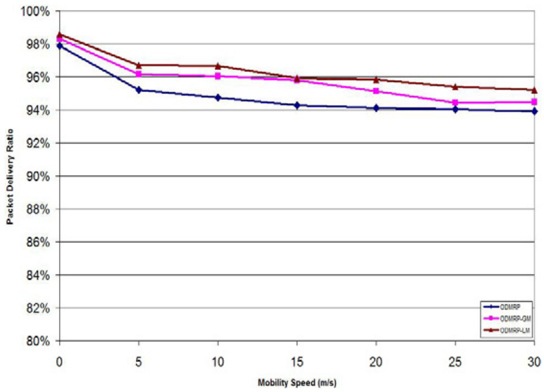

Fig. 3. Packet Delivery Ratio as a function of mobility speed.

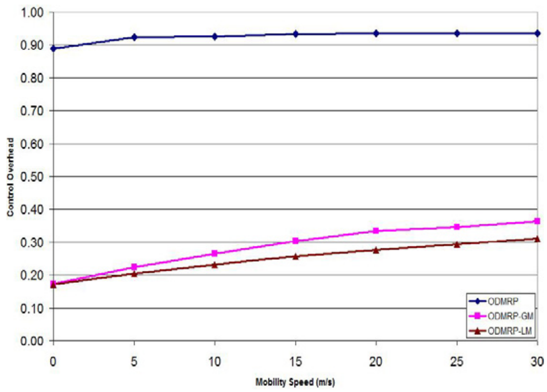

Fig. 4. Control Overhead as a function of mobility speed.

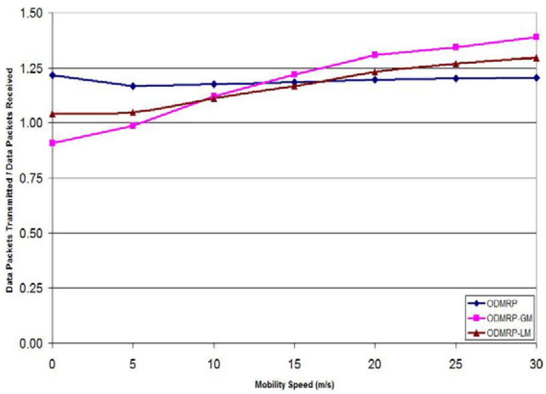

Fig. 5. Number of data packets transmitted per data packet delivered as a function of mobility speed.

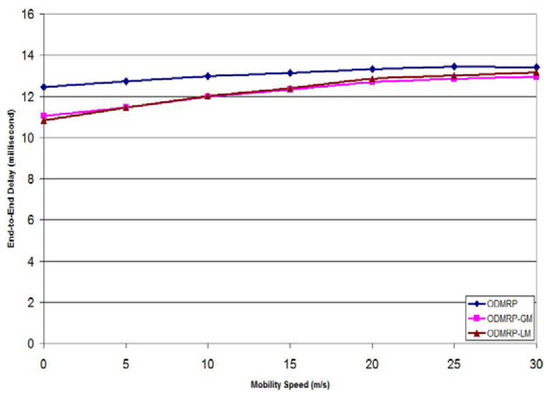

Fig. 6. Number of control and data packets transmitted per data packet delivered as a function of mobility speed.

Control Overhead Figure 4 shows the control overhead as a function of mobility speed for each scheme. We see from the figure that the original ODMRP requires a very high control overhead compared to the proposed schemes. The two proposed schemes ODMRP-GM and ODMRP-LM decrease the control overhead by up to 81% less than ODMRP for each data packet delivered when there is no mobility (0m/s), and they decrease the control overhead by up to 67% less than the original one at mobility speed 30m/s. We can also see from the figure that changing the speed of nodes has no effect on the control overhead for the original protocol because it floods the Join Queries periodically without adapting to mobility patterns. When the mobility of nodes is low, the routes are rarely broken and the prediction algorithm is not applied; as a result, the proposed schemes yield far fewer control packets than the original ODMRP which means that the control overhead is highly minimized. However, when the mobility is high, the routes are frequently broken and the prediction algorithm is applied to find alternative routes and update the forwarding group nodes. Therefore, the control overhead increases because more control packets are needed to update the routes and maintain the forwarding group nodes.

Number of data packets transmitted per data packet delivered Figure 5 shows the number of data packets transmitted per data packet delivered as a function of mobility speed for each scheme. In other

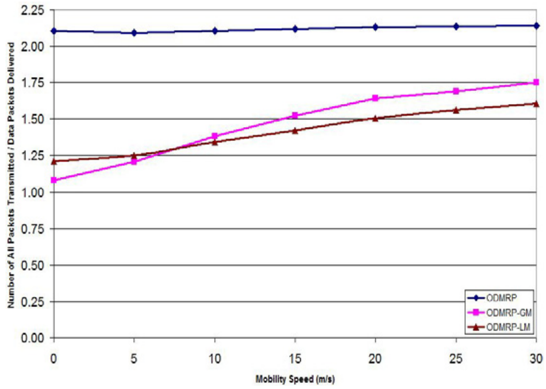

Fig. 7. End-to-End delay as a function of mobility speed.

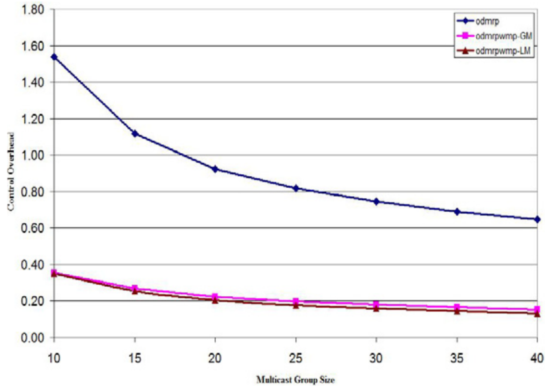

Fig. 8. Control Overhead as a function of multicast group size.

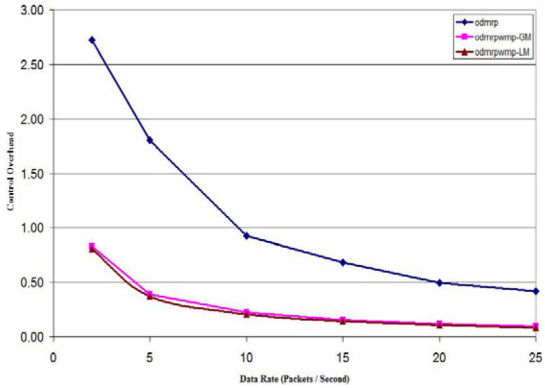

Fig. 9. Control Overhead as a function of data rate.

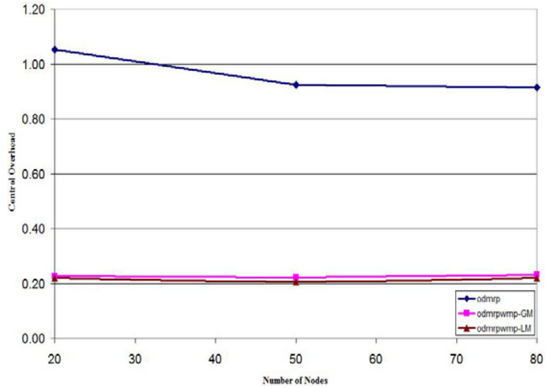

Fig. 10. Control Overhead as a function of number of nodes.

words, this metric represents the data overhead incurred by each protocol. Both proposed schemes have higher data overhead than the original ODMRP in the case of low mobility (less than or equal to $15m/s$) to reach (up to 25% and 15%) for ODMRP-GM and ODMRP-LM, respectively. The data overhead begins to increase more than the original ODMRP in case of high mobility (more than $15m/s$) to reach (up to 14% and 8%) for ODMRP-GM and ODMRP-LM, respectively. However, why does the data overhead for the proposed schemes increase when we increase the speed of nodes? This is because they still forward data packets over the old routes that will be broken imminently in addition to forwarding data packets over the new alternative routes. The proposed schemes do not implement any way to prune the old routes that are going to be broken imminently. Another reason for this increase is that the new alternative routes are usually longer than the old ones. Thus, the data packets are forwarded more times over the intermediate nodes.

Number of control and data packets transmitted per data packet delivered Figure 6 shows the number of control and data packets transmitted per data packet delivered as a function of mobility speed for each scheme. This is an important metric that gives an indication of whether the channels are accessed efficiently or not. From Figure 6, we can see an improvement in the channel access efficiency for the proposed protocols over the original one. ODMRP-GM and ODMRP-LM improve the channel access efficiency by 49% and 43%, respectively, less than ODMRP for each data packet delivered when there is no mobility ($0m/s$). In the same way, they also decrease the control overhead by 18% and 25%, respectively, less than the original one at mobility speed $30m/s$. Figure 6 shows clearly that the channel access efficiency decreases in the proposed schemes with the increase in the speed of the nodes. Because the proposed schemes adapt to the mobility patterns, more control and data packets are forwarded and fewer data packets are delivered to their destinations when the speed of nodes increases. In contrast, the original ODMRP does not adapt to mobility patterns and its channel access is always inefficient regardless of the mobility speed.

End-to-End Delay Figure 7 illustrates the end-to-end delay of the simulated protocols under different speeds. We can see that both of ODMRP-GM and ODMRP-LM give short end-to-end delays than the original ODMRP. ODMRP-GM and ODMRP-LM decrease the end-to-end delay by 13% less than the original ODMRP when there is no mobility ($0m/s$), and they decrease the end-to-end delay by 3% less than the original one at mobility speed $30m/s$. When the mobility of nodes is low, the routes are rarely broken and the prediction algorithm is not applied; as a result, the shortest routes are always used and the forwarding group size is kept small, which means that the data packets need less delay to reach their destinations. However, when the mobility is high, the routes are frequently broken and the prediction algorithm is applied to find alternative routes and update the forwarding group nodes. The alternative routes are usually longer than the old ones. Thus, the data packets take more time to reach their destinations. In addition, the increase of the speed in the proposed schemes yields more control packets; therefore, congestion and collisions are more likely to happen due to the limited bandwidth, which means an increase in the end-to-end delay.

6. Conclusion

In this paper, we proposed two schemes to improve the performance of ODMRP by reducing its high control overhead. Both schemes utilize signal power strengths of received packets to predict active routes breakage time in advance. Moreover, both of them increase the flooding interval value and reconstruct active multicast routes only when they will be imminent broken. Thus, control overhead is considerably reduced, bandwidth is utilized efficiently, and power consumption is economized when mobility of nodes is low.

Simulation results show that the addition of the link state prediction method that uses the received signal power strength to ODMRP has significantly reduced the high control overhead in case of low mobility. However, in case of high mobility, the data overhead is increased more than the original ODMRP for both proposed schemes because they do not prune old routes that continue forwarding multicast data packets. The simulation results also show an improvement in channel access efficiency, while the end-to-end delay is minimized too. For future work, we plan to enhance the proposed schemes by finding ways to prune the old routes that are going to break imminently to minimize the data overhead when the mobility of nodes is high. We also plan to apply the proposed schemes on the unicast version of the ODMRP.

References

[1] A. Mukherjee, D. Saha, S. Bandyopadhyay, Location Management and Routing in Mobile Wireless Networks, Artech House, Inc., Norwood, MA, USA, 2001.

[2] S. Corson, J. Macker, Mobile ad hoc networking (manet) : Routing protocol performance issues and evaluation considerations, IETF RFC 2501 (http://www.ietf.org/rfc/rfc2501.txt).

[3] L. Junhai, X. Liu, Y. Danxia, Research on multicast routing protocols for mobile ad-hoc networks, Computer Networks 52 (5) (2008) 988–997.

[4] S.-J. Lee, W. Su, M. Gerla, Wireless ad hoc multicast routing with mobility prediction, Mob. Netw. Appl. 6 (2001) 351–360.

[5] S. Y. Oh, J.-S. Park, M. Gerla, E-odmrp: Enhanced odmrp with motion adaptive refresh, Journal of Parallel and Distributed Computing 68 (8) (2008) 1044–1053.

[6] Y. Yi, S.-J. Lee, W. Su, M. Gerla, Mobile ad hoc networking (manet) : Routing protocol performance issues and evaluation considerations, Internet-Draft (http://tools.ietf.org/id/draft-ietf-manet-odmrp-04.txt).

[7] C. Chiang, M. Gerla, L. Zhang, Forwarding group multicast protocol (fgmp) for multihop, mobile wireless networks, Cluster Computing 1 (1998) 187–196.

[8] M. Naderan-Tahan, A. Darehshoorzadeh, M. Dehghan, Odmrp-lr: Odmrp with link failure detection and local recovery mechanism, in: Computer and Information Science. ICIS'09. 8th IEEE/ACIS International Conference on, 2009, pp. 818–823.

[9] S.-J. Lee, W. Su, M. Gerla, On-demand multicast routing protocol in multihop wireless mobile networks, Mobile Networks and Applications 7 (2002) 441–453.

[10] L. Qin, T. Kunz, Increasing packet delivery ratio in dsr by link prediction, in: System Sciences, 2003. Proceedings of the 36th Annual Hawaii International Conference on, HICSS '03, IEEE Computer Society, Washington, DC, USA, 2003, p. 300a.

[11] S.-J. Lee, Routing and multicasting strategies in wireless mobile ad hoc networks, Ph.D. thesis (2000).

[12] X. Zeng, R. Bagrodia, M. Gerla, Glomosim: a library for parallel simulation of large-scale wireless networks, in: Parallel and Distributed Simulation, 1998. PADS 98. Proceedings. Twelfth Workshop on, 1998, pp. 154–161.

[13] R. Bagrodia, R. Meyer, M. Takai, Y.-A. Chen, X. Zeng, J. Martin, H. Y. Song, Parsec: a parallel simulation environment for complex systems, Computer 31 (10) (1998) 77–85.

[14] S. Taneja, A. Kush, A survey of routing protocols in mobile ad hoc networks, International Journal of Innovation Management and Technology (IJIMT) 1 (3) 2010.